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ABSTRACT

Investigated are two instructional treatments, inductive and deductive teaching methods, and the possible interaction between these treatments and the cognitive style dimension of field-dependence-independence. The subject matter was transformational geometry and the criterion measures included an examination testing knowledge, application, analysis, and transfer. Subjects were elementary education majors. The results indicate the possibility that the students who exhibited a field-dependent cognitive style learned more from the inductive method. The field-independent students were not significantly affected by the teaching method. (Author/MP)

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THE EFFECTS OF INDUCTIVE-DEDUCTIVE TEACHING METHODS AND FIELD-DEPENDENCE-INDEPENDENCE COGNITIVE STYLE UPON STUDENT ACHIEVEMENT IN MATHEMATICS

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THE EFFECTS OF INDUCTIVE-DEDUCTIVE TEACHING METHODS AND FIELD-DEPENDENCE-INDEPENDENCE COGNITIVE STYLE UPON STUDENT ACHIEVEMENT IN MATHEMATICS

A recurring theme throughout a vast majority of the literature written on education in the last ten years has been the need to individualize education, i.e., to meet the needs of the students at all levels of education (Cronbach and Snow, 1969; Bloom, Hastings and Madaus, 1971; Glaser, 1972; Coop and Sigel, 1971). Educators devise and apply instructional treatments, continually seeking improved results. One approach is to search for "the best method of instruction" (Cronbach and Snow, 1969). But pupils differ and the search for the generally superior method must be supplemented with ways of adapting instruction to the needs and abilities of the individual. In fact, "individualization" has become an educational slogan for many schools and numerous curricular materials. However, few of these programs have examined carefully "the inter-individual variability of the learners who will be exposed to their educational stimuli" (Coop and Sigel, 1971, p. 152). Thus, research needs to be done on the many consistent individual differences of students and the interactions between these differences and instructional procedures.

Within the last two decades a type of research has emerged which attempts to investigate how these individual differences modify treatment effects (Cronbach, 1957). This type of research is referred to in the literature as aptitude-treatment interaction (ATI) research. It is based on the premise that educators cannot ignore interactions between student aptitudes and treatments, but rather must adapt instructional treatments

to student differences. An interaction is present when one treatment is significantly better for one type of student, while a different treatment is significantly better for another type of student (Koran, 1973). ATI research represents an approach to research rather than a clearly defined research area. The investigations reported have not always produced consistent results (Cronbach and Snow, 1969). However, many researchers feel that research directed at finding aptitude-treatment interactions must not be discontinued.

The aptitude of cognitive style has gained the attention of many researchers in recent years. One dimension of cognitive style is that of field-dependence-independence, first studied by Witkin and his colleagues in 1950. Relative to this aptitude people may be placed along a continuum with field-dependence and field-independence at the extremes on the basis of the ease with which they perceive items as discrete from their backgrounds. A field independent person perceives all aspects of his environment analytically in that he experiences items as discrete from their backgrounds, while a field-dependent individual perceives his surroundings globally, where the embedding field strongly determines his perception of its parts. In addition to this, people who experience analytically are also better able to structure their experiences. Field-independent people are more likely than field-dependent people to impose an organization upon ambiguous stimulus material (Witkin et al., 1962). This dimension then obviously embodies both the perceptual and intellectual functioning of individuals. For example, students at the extremes of the field-dependent-independent dimension differ in the mix of courses they take, but not in their overall grade-point averages. Students who

as a group are field-independent tend to choose courses in the natural sciences and mathematics (Witkin, 1974).

In ATI research, the term treatment has been broadly defined to include "variations in structure, pacing, style or modality of instruction" (Koran, 1973, p. 112). One pair of treatments which has received considerable attention not only in ATI research, but in all types of studies, is the inductive versus deductive paradigm. The interpretations given to these terms appear to vary with each researcher. In the Dictionary of Education, inductive teaching is defined as being "based on the presentation to the learner of a sufficient number of specific examples to enable him to arrive at a definite rule, principle or fact" (Good, 1959). Deductive teaching is defined as a method "that proceeds from rules or generalizations to examples and subsequently to conclusions or to the application of the generalizations" (Good, 1959). It is interesting to note that in the definition of inductive teaching nothing is said about a statement of the rule or principle. According to this definition, it is not a necessary part of inductive teaching to state the generalization for the student or to have him state it after exposure to the examples. In the literature an inductive instructional procedure is often referred to as the egrule method (example-rule), while a deductive approach is referred to as the ruleg method (rule-example).

Few areas of educational research produce as many contradictory results as do the studies on inductive versus deductive teaching. The results of studies dating back to the 1950's fail to overwhelmingly support either instructional method.

Hermann wrote an article, "Learning by Discovery: A Critical Review of Studies," in 1969 in which he tabulated and discussed the findings of research comparing inductive and deductive teaching methods from 1956. He did, however, also include the 1947 study by Hendrix. He examined 46 experimental results and categorized these as to whether significance was found for criterion measures of early retention, early transfer, late retention, and late transfer. Of the 46 results, no significant differences were reported in 29 of them, twelve showed the inductive method to be superior on one of the measures, and the remaining five showed the deductive method to be superior. As a final comparison, he also classified the results with respect to type of material to be learned. Nine results were classified under mathematics, with six of these showing no significant difference, two favoring the inductive method, where early and late transfer were the criterion measures, and one showing the deductive method to be superior, when early retention was the criterion measure. These results do not show an outstanding superiority of either method, and hence indicate that more research needs to be done in this area.

This study was an investigation of two instructional treatments, inductive and deductive teaching methods. In addition to testing the main effects of these treatments, the possible interaction between these treatments and the cognitive style dimension of field-dependence-independence was examined. The subject matter that was taught was selected concepts from transformational geometry. The criterion measures included an overall achievement test which contained knowledge, application, analysis and transfer subtests.

METHOD

Subjects

The sample for this study included those students enrolled in and attending the second semester of a course entitled Modern Elementary Mathematics, a two-semester course designed specifically for students who are elementary education majors. Two sections of the course were offered during the second semester of the 1976-1977 school year and both sections were utilized in this investigation. The two sections were randomly assigned to either the inductive or the deductive treatment. The group receiving the inductive treatment had 47 students and the one receiving the deductive treatment contained 71 students.

Treatments

After careful consideration of studies on various instructional procedures, inductive and deductive teaching methods were chosen for this study. Introductory material and basic definitions in transformational geometry necessary to the unit were the same in both treatments. The deductive treatment basically followed a rule-example paradigm. A rule or principle was stated and explained for the students, after which several examples were worked by the teacher and students together in class. The rule or principle was written out for the students by the teacher while it was being stated.

The inductive treatment followed basically an example-rule paradigm. In this treatment, numerous examples were worked by the teacher and students before a rule or principle was expected. Following the examples, the students were encouraged, via questions, to formulate a principle of their own. However, the formulating of a rule or principle was never

done for them by the teacher.

The transformational geometry units were taught to both university classes within the same two-week period. Both experimental groups received a total of two hours and thirty minutes of instruction. All teaching sessions were recorded on a cassette tape-recorder and later evaluated to confirm that the written lesson plans were followed as closely as was possible.

Instruments

The Group Embedded Figures Test (GEFT), developed by Witkin and his colleagues (1954, 1962), was the instrument utilized to place the students in this study along the field-dependent-independent continuum. It was designed to provide a group version of the individually administered Embedded Figures Test (EFT). With the GEFT, scores for many individuals can be obtained in a single twenty-minute testing session. A complete discussion of the test can be found in Witkin, Oltman, Rasking and Karp, 1971.

The criterion measure for this teaching unit was an overall achievement test. The researcher developed the instrument by consulting the Taxonomy of Educational Objectives (Bloom, et al., 1956) to write items representing the levels of Bloom's taxonomy. This compilation of possible questions was then given to people knowledgeable in mathematics and education who were asked to furnish suggestions. The final instrument consisted of 22 objective items. For purposes of analyzing the data, these items were classified by this researcher, in agreement with those consulted, into knowledge, application and analysis items based

upon Bloom's (1956, 1971) criteria. The application and analysis items were further grouped together for the data analysis and referred to as the transfer subtest.

Results

An analysis of variance was employed to test for the main effects of the inductive and deductive teaching methods. Tables 1 and 2 summarize the results of the ANOVA data analysis for the analysis and transfer subtests.

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Insert Tables 1 & 2 about here
- -

A one-way ANOVA was done on each of the five criterion measures (overall achievement, knowledge subtest, application subtest, analysis subtest and transfer subtest). Differences, significant beyond the .05 level, were found between the group means on the transfer and analysis subtests. Both differences were in the direction favoring the inductive treatment. It should be noted, however, that these results are not independent since the transfer subtest was made up of the application and analysis items of the overall achievement instrument. In all of the comparisons, the mean for the inductive group was higher than that of the deductive group, but only for the analysis and transfer subtests were these differences significant.

Pearson product moment correlation coefficients between the measures of achievement and between these and the GEFT were computed separately for each treatment group. These are presented in Tables 3 and 4.

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Insert Tables 3 & 4 about here
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It should be noted that many of the correlation coefficients were significant. This was especially true for the deductive group, where the only correlation not significant was between the knowledge and application subtests.

One of the major areas of concern in this study was the investigation of aptitude-treatment interactions between the cognitive style dimension of field-dependence-independence and the inductive-deductive instructional procedures. The ATI hypotheses were tested using linear regression analysis. For a given criterion measure, the regression lines for the two treatments were compared and tested for a possible disordinal interaction.

The initial step in testing the interaction hypotheses using linear regression analysis was to check the appropriateness of the model for the data. First, the standardized residuals were plotted against their corresponding X-scores. A visual inspection of these graphs supported the assumption of linearity across the subpopulations in each graph. Furthermore, in each graph, the overall distance of the standardized residuals from the line $e_i = 0$ did not change for different X-values. Hence, the condition of homoscedasticity appeared to be satisfied. An informal check was made on the assumption that the Y-scores were normally distributed about the subpopulation means. This was done by examining the cumulative frequency distributions of the treatment groups for each of the criterion measures. The distributions appeared to be negatively skewed, although not enough to affect the results based upon the use of the F statistic.

A test of the independence or randomness of the residuals was carried out using the Durbin-Watson statistic. The computed values of the statistic are presented in Table 5 for those cases where interaction was later found. As can be seen, the hypothesis that the residuals are independent was retained.

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Insert Table 5 about here
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Final checks of the appropriateness of the model for the data were F statistics computed to test the departure from linearity of the subpopulation means and the equality of the subpopulation variances between the treatment groups. This analysis showed compliance with the model for the criterion measure of overall achievement and minimal deviation of the equality of the subpopulation variance for the transfer subtest.

The regression analysis of the data indicated strong support ($.05 < p < .1$) for the existence of aptitude-treatment interactions between field-dependence-independence and the instructional procedures for the criterion measures of overall achievement and transfer. Tables 6, 7, 8 and 9 present the statistics pertinent to these findings.

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Insert Tables 6 - 9 about here
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For both criterion measures, the regression lines intersected within the range of scores for the GEFT. The graphs of the pairs of lines for each criterion measure are pictured in Figures 1 and 2.

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Insert Figures 1 and 2 about here
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The Johnson-Neyman technique (Johnson & Neyman, 1936; Johnson & Jackson, 1959) was utilized to provide information on the regions of significant differences for these interactions. A .05 level of significance was chosen. When overall achievement was the criterion measure, it was found that all individuals having GEFT scores of five or below out of a possible 18 performed better if they were taught by the inductive method. For other individuals, the choice of method (inductive or deductive) did not result in a difference in achievement. When the transfer subtest was the criterion measure, further analysis of the data indicated that all individuals having a GEFT score of nine or below performed better if they were taught by the inductive method. For other individuals, the choice of method did not result in a significant difference in achievement.

DISCUSSION

The ATI results of this study are not in agreement with the conjectures of Witkin et al. (1962) and Messick (1970). These researchers felt that the field-dependent student would learn better under a deductive teaching method while the field-independent student would learn better under an inductive approach. The results of this study indicate the possibility that the students who exhibited a field-dependent cognitive style learned more, as measured by the overall achievement and transfer tests, from the inductive method. Furthermore, for the field-independent

students, the teaching method did not significantly affect achievement. They learned equally well under either method.

These results can be interpreted in the light of some of the characteristics of field-dependent and field-independent persons. Field-dependent people have been found to be more socially inclined than field-independent persons. Field-dependent people have been found to be more socially inclined than field-independent people. It could have been that the field-dependent students in this study achieved more with the inductive method, due to the social interaction it afforded them. In the inductive method the students spent time working problems and at times comparing their solutions with those of the students around them. This was not the case in the deductive method. Very little social interaction occurred because much class time was spent with the instructor stating and explaining the rules and principles. The field-independent students, however, were not affected by the difference in the amount of social interaction occurring during the class periods. The inductive treatment did not force any of the students to socially interact, but did allow it for those who wanted to do so. The treatments, in this respect at least, did not make a difference in the amount that the field-independent students applied themselves to the learning task. Hence, a possible cause for the lack of a significant difference on the criterion measures for the more field-independent learners was this characteristic of social interaction.

TABLE 1

Analysis of Variance Summary Table for the Analysis Subtest for Inductive and Deductive Treatment Groups

Source	SS	df	MS	F	P
Between Groups	4.8785	1	4.8785	4.148	.044
Within Groups	136.4435	116	1.1762		
Total	141.3220	117			

TABLE 2

Analysis of Variance Summary Table for Transfer Subtest for Inductive and Deductive Treatment Groups

Source	SS	df	MS	F	P
Between groups	15.2189	1	15.2189	5.130	.025
Within groups	344.1031	116	2.9664		
Total	359.3220	117			

TABLE 3

Correlation Coefficients within Inductive Group[a]

	Correlations					
Instrument	1	2	3	4	5	6
1. GEFT	—	.29*	.22	.27*	.09	.25*
2. Overall Achievement		---	---	---	---	---
3. Knowledge			---	.45*	.10	.39*
4. Application				---	-.05	---
5. Analysis					---	---
6. Transfer						---

[a] N = 47

*Significant at the .05 level

TABLE 4

Correlation Coefficients within Deductive Group[a]

Instrument	Correlations					
	1	2	3	4	5	6
1. GEFT	---	.54*	.41*	.37*	.39*	.47*
2. Overall Achievement		---	---	---	---	---
3. Knowledge			---	.17	.36*	.33*
4. Application				---	.26*	---
5. Analysis					---	---
6. Transfer						---

[a] N = 71

*Significant at the .05 level

TABLE 5

Values of Durbin-Watson Statistic

Independent Variable	Durbin-Watson Statistic
Overall Achievement	
Inductive Group	1.90[a]
Deductive Group	2.27[b]
Transfer	
Inductive Group	2.24[a]
Deductive Group	2.40[b]

[a] Critical value at .05 level of significance is $D \leq 1.29$

[b] Critical value at .05 level of significance is $D \leq 1.43$

TABLE 6

Regression ANOVA Summary Table for Overall Achievement Test

Source	SS	df
Regression		
Inductive Group	13.65008	1
Deductive Group	130.90523	1
Residual		
Inductive Group	151.62651	45
Deductive Group	318.08069	69
Total		
Inductive Group	165.27659	46
Deductive Group	448.98492	70

TABLE 7

Statistics for Regression of Overall Achievement on GEFT Score

Statistic	Value
Correlation Coefficient, R	
Inductive Group	.28738
Deductive Group	.63996
Correlation Coefficient Squared, R^2	
Inductive Group	.08259*
Deductive Group	.29156**
Standard Error of Estimate, $\sigma_{y \cdot x}$	
Inductive Group	1.83561
Deductive Group	2.14706
Slope of Regression Line, b	
Inductive Group	.12262117
Deductive Group	.27600734
Intercept of Regression Line, a	
Inductive Group	17.373582
Deductive Group	15.331760

*p = .050

**p = .000

TABLE 8

Regression ANOVA Summary Table for Transfer Subtest

Source	SS	df
Regression		
Inductive Group	4.56602	1
Deductive Group	61.36709	1
Residual		
Inductive Group	66.07228	45
Deductive Group	212.09770	69
Total		
Inductive Group	70.6383	46
Deductive Group	273.46478	70

TABLE 9

Statistics for Regression of Transfer Achievement on GEFT Score

Statistic	Value
Correlation Coefficient, R	
Inductive Group	.25424
Deductive Group	.47371
Correlation Coefficient Squared, R^2	
Inductive Group	.06464*
Deductive Group	.22441**
Standard Error of Estimate, $\tilde{\sigma}_{y \cdot x}$	
Inductive Group	1.21172
Deductive Group	1.75325
Slope of Regression Line, b	
Inductive Group	.070919659
Deductive Group	.18897741
Intercept of Regression Line, a	
Inductive Group	9.3403019
Deductive Group	7.6000787

* p = .085

**p = .000

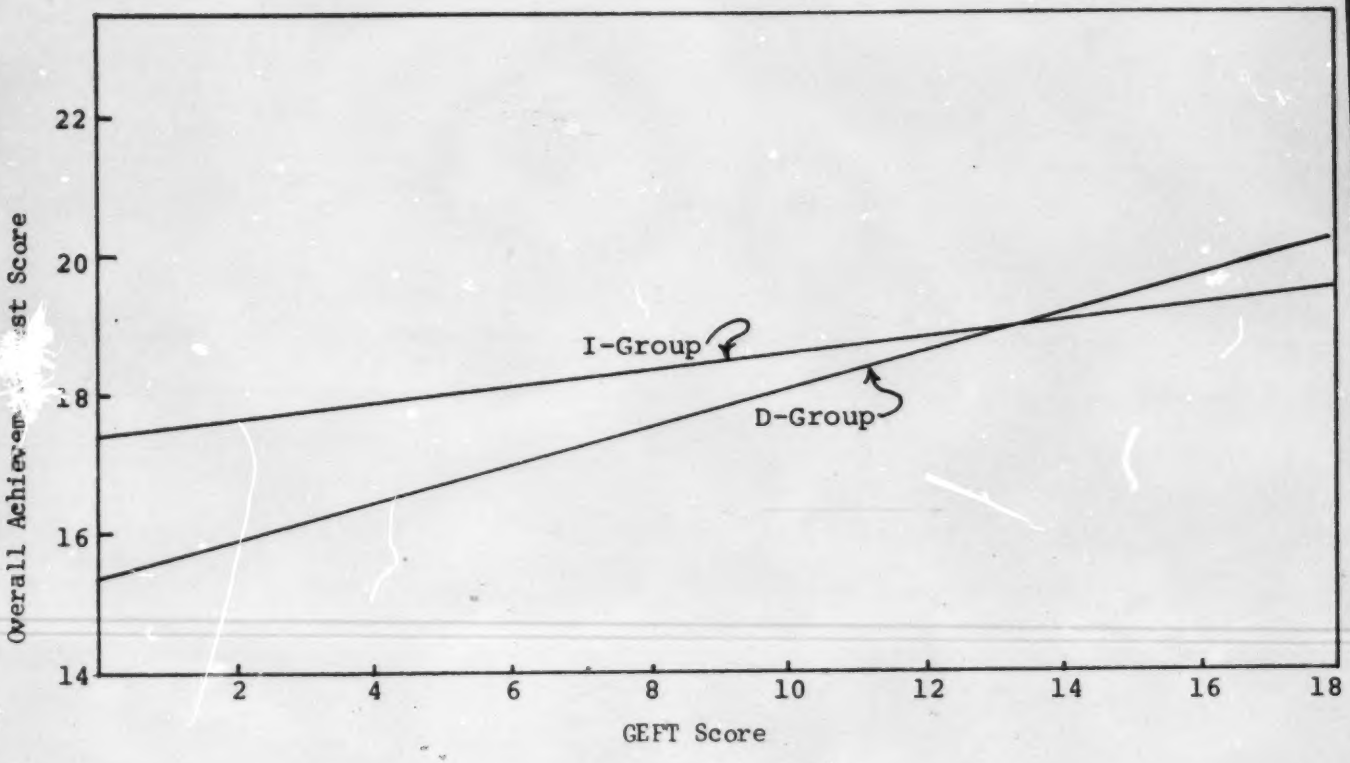

Figure 1. Regression Lines for Overall Achievement Test Score on GEFT Score

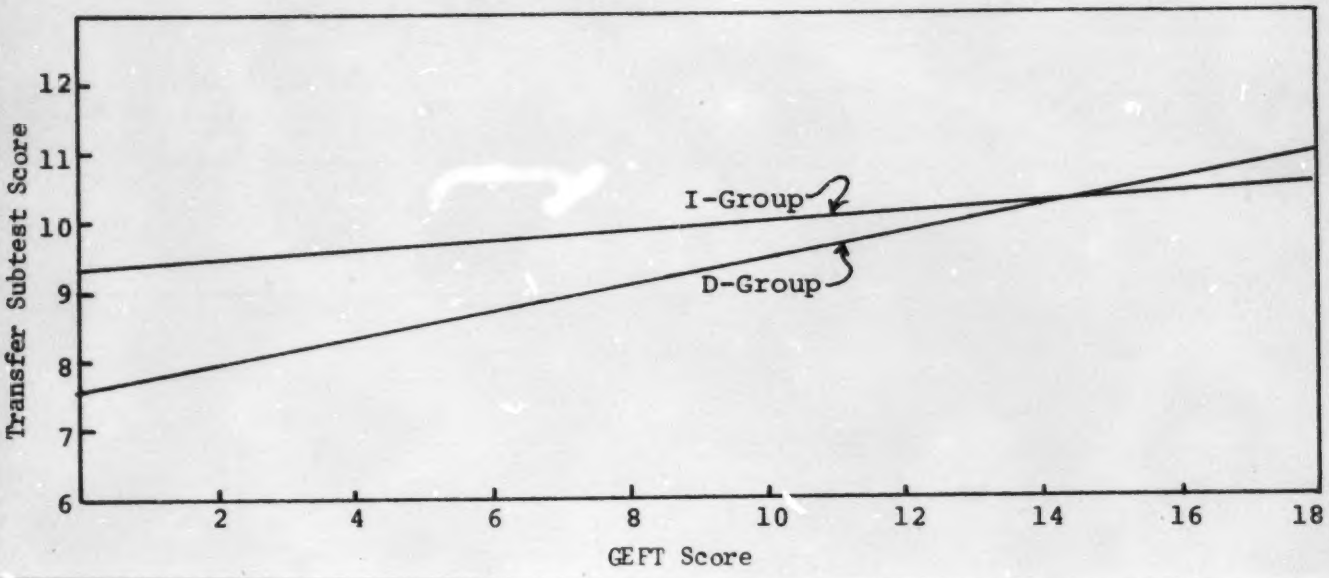

Figure 2. Regression Lines for Transfer Subtest Score on GEFT Score

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